Assessment of alternative divertor configurations as an exhaust solution for DEMO

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Nucl. Fusion **60** (2020) 066030; https://doi.org/10.1088/1741-4326/ab8a6a

Abstract:

Plasma exhaust has been identified as a major challenge towards the realisation of magnetic confinement fusion. To mitigate the risk that the single null divertor (SND) with a high radiation fraction in the scrape-of-layer (SOL) adopted for ITER will not extrapolate to a DEMO reactor, the EUROfusion consortium is assessing potential benefits and engineering challenges of alternative divertor configurations. Alternative configurations that could be readily adopted in a DEMO design include the X divertor (XD), the Super-X divertor (SXD), the Snowflake divertor (SFD) and the double null divertor (DND). The flux flaring towards the divertor target of the XD is limited by the minimum grazing angle at the target set by gaps and misalignments. The characteristic increase of the target radius in the SXD is a trade-off with the increased TF coil volume, but, ultimately, also limited by forces onto coils. Engineering constraints also limit XD and SXD characteristics to the outer divertor leg with a solution for the inner leg requiring up-down symmetric configurations. Capital cost increases with respect to a SND configuration are largest for SXD and SFD, which require both significantly more poloidal field coil conductors and in the case of the SXD also more toroidal field coil conductors. Boundary models with increasing degrees of complexity have been used to predict the beneficial effect of the alternative configurations on exhaust performance. While all alternative configurations should decrease the power that must be radiated in the outer divertor, only the DND and possibly the SFD also ease the radiation requirements in the inner divertor. These decreases of the radiation requirements are however expected to be small making the ability of alternative divertors to increase divertor radiation without excessive core performance degradation their main advantage. Initial 2D fluid modeling of argon seeding in XD and SFD configurations indicate such advantages over the SND, while results for SXD and DND are still pending. Additional improvements, expected from increased turbulence in the low poloidal field region of the SFD also remain to be verified. A more precise comparison with the SND as well as absolute quantitative predictions for all configurations requires more complete physics models that are currently only being developed.